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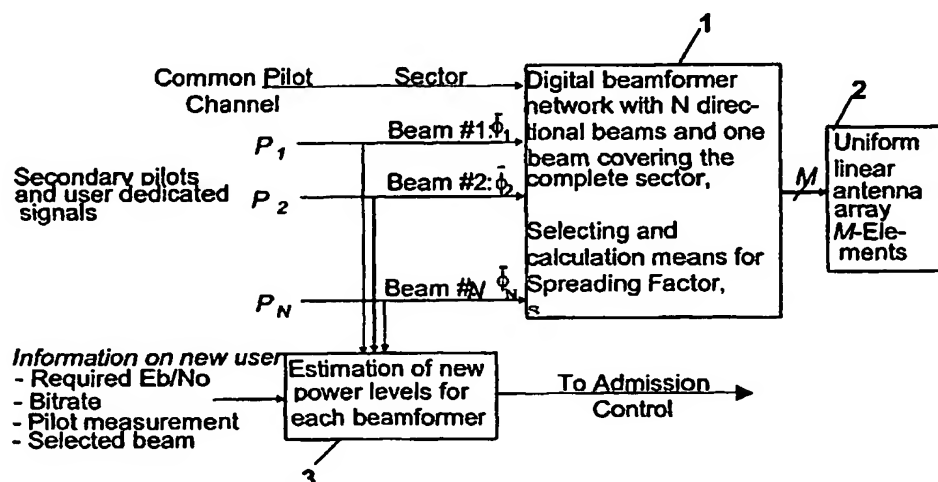
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(54) Title: SYSTEM AND METHOD FOR OPTIMIZED UTILIZATION OF CODE RESOURCE IN COMMUNICATION NETWORKS



(57) Abstract: The invention provides a method, system and network element for providing enhanced utilization of code resource in a cellular systems, preferably a terrestrial cellular CDMA systems, wherein a base station comprises an antenna system which generates several beams A spreading factor (SF) of the root channelization code sets an upper limit on the maximum bit rate. The spreading factor of the root channelization code is selected according to the set of minimum spreading factors assumed for the different beams. Packet scheduling for parallel beams is provided in such a manner that not all beams transmit on downlink, e.g. PDSCH, with high or maximum bit rates (low Spreading Factor) simultaneously. The packet scheduling in the individual beams is coordinated so that only one of the beams is transmitting with a high bit rate during the same time period. Different scheduling slots are balanced so they require nearly the same amount of code resources.

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**SYSTEM AND METHOD FOR OPTIMIZED UTILIZATION OF  
CODE RESOURCE IN COMMUNICATION NETWORKS**

5

**FIELD AND BACKGROUND OF THE INVENTION**

The present invention relates to a system and method for enhancing utilization of code resource in terrestrial or cellular systems, preferably to terrestrial cellular CDMA (Code Division Multiple Access) systems and methods.

The invention addresses issues related to cellular systems, e.g. terrestrial cellular CDMA systems, where there is a need for optimized utilization of code resource. This is e.g. the case for the downlink of UMTS (Universal Mobile Telecommunication System), where a finite set of channelization codes are available. It is known that problems may arise when advanced capacity enhancing features are being introduced such as e.g. smart antennas (SA).

**SUMMARY OF THE INVENTION**

According to one aspect, the invention provides a method as defined in the independent method claim.

According to a further aspect, the invention provides a system as defined in the independent system claim.

According to another aspect, the invention provides a network element as defined in the independent network element claim.

The invention provides a code efficient solution for cases where multiple beamforming channels, preferably PDSCHs (PDSCH

= Physical Downlink Shared Channel) are applied.

The method, system and network element in accordance with  
embodiments of the invention preferably provide a code  
5 trunking efficient solution. This means that code resources  
are better utilized, so the BS (Base Station) can carry a  
higher amount of traffic (e.g. higher number of user) with  
less scrambling codes. This is a major advantage, as  
introduction of additional scrambling codes typically results  
10 in a capacity loss, as the orthogonality properties are  
partly destroyed within the cell. The invention therefore  
results in a capacity gain.

This gain is also present for HSDPA (High Speed Downlink  
15 Packet Access), even though HSDPA has the option of using  
higher order modulation schemes to avoid code blocking. This  
is true since usage of multiple codes (equivalent to lower  
spreading factor) is more spectral efficient, compared to  
using higher order modulation techniques.

20

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a block diagram of BS architecture in an  
25 embodiment of a system in accordance with the invention when  
using smart antennas with a grid of fixed downlink  
beamforming,

Fig. 2 illustrates beam allocation of primary and  
30 secondary scrambling code, physical channels carrying data,  
and common broadcast channels, in case of cell splitting, of  
an embodiment of a system and method in accordance with the  
invention,

35 Fig. 3 shows an illustration of a channelization code

tree for under one scrambling code. The black nodes in the tree are reserved for PDSCHs under different beams,

Fig. 4 illustrates an example of smart parallel packet scheduling for optimized code resource allocation, in an embodiment of a system and method in accordance with the invention, and

Fig. 5 shows an example of poor un-coordinated packet scheduling.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

15

Fig. 1 shows a basic structure of a system in accordance with an embodiment of the invention. Fig. 1 illustrates a block diagram of a BS (base station) architecture when using smart antennas with a grid of fixed downlink beamforming. The system of Fig. 1 involves a network element implemented as a digital beamformer network 1 which generates N directional beams and one beam covering the complete sector. The beamformer network 1 preferably includes two or more up to M beamformers, and sends M signals to a uniform linear antenna array 2 which comprises M antenna elements. The beamformer network 1 includes a selection means for selecting spreading factors, in particular a minimum Spreading Factor for the beams.

30 The beamformer network 1 receives the signals of the common pilot channel and of the secondary pilots and user dedicated signals  $P_1$  to  $P_N$  and forms there from the M antenna signals to be applied to the antenna array 2.

35 An estimation means 3 calculates, i.e. estimates, new power

levels for each beamformer of the beamformer network 1,  
condition on admission of a new user with certain QoS  
(quality of service) attributes. The estimation means 3  
receives the the current average transmit power on the N  
5 beams ( $P_1$  to  $P_N$ ), the average transmit power of the sector  
beam as well as information on new user(s) such as required  
Eb/No, bit rate, pilot measurement from the user, selected  
beam. The estimation means 3 generates input to radio  
resource management algorithms such as AC (admission  
10 control).

The present invention also addresses issues related to  
optimized utilization of code resource in cellular systems,  
e.g. terrestrial cellular CDMA systems. In some cases, e.g.  
15 for downlink of UMTS, only a finite set of channelization  
codes is available. This causes some potential problems when  
advanced capacity enhancing features are to be introduced  
such as e.g. smart antennas (SA).

20 In this implementation of the invention, the example case of  
introducing SA (smart antenna) at the BS in UMTS is  
discussed, and a method and structure for effectively  
utilizing code resources are shown. In particular the down  
link shared channel (DSCH) is considered, which is  
25 particularly suited for bursty high bit rate packet traffic.  
Embodiments of the invention also cover the enhanced DSCH  
called the high speed downlink packet access channel (HSDPA).

For the downlink (DL), a finite set of fixed directional  
30 beams is assumed, where each beam carries a secondary common  
pilot channel (S-CPICH). In addition, it is assumed that a  
beam (sector beam) is provided which covers the complete  
sector.

35 A block diagram for the DL control is pictured in Figure 1.

All channels which must be broadcast in the entire cell are therefore transmitted on the sector beam shown by a dotted line in Fig. 2, while dedicated channels are transmitted on the directional beams (beams 1 to 8) shown in Fig. 2 by dotted and dot-and-dash lines. This is illustrated in Figure 2, where the following channels CCPCH, CPICH, AICH, PICH, and SCH are transmitted on the sector beam, while DPCHs are transmitted under narrow directional beams. (CCPCH Common Control Physical Channel, CPICH Common Pilot Channel, AICH Acquisition Indication Channel, PICH Paging Indication Channel, SCH Synchronization Channel)

Note that beamforming on PDSCH also is possible. Different scrambling codes can also be allocated to each beam in order to avoid potential channelization code shortage.

In general, it is typically found that the capacity gain from introducing beamforming antennas is so large, that at least 2 to 3 scrambling codes are needed per cells in order to avoid channelization code blocking (i.e. hard blocking).

As an example, Figure 2 shows a case where two scrambling codes are deployed, so each scrambling code covers four directional beams. The primary scrambling code is used for the directional beams 1 to 4 shown at the left half portion of Fig. 2, whereas the secondary scrambling code is used for the directional beams 5 to 8 shown at the right half portion of Fig. 2.

Fig. 2 graphically illustrates the beam allocation of primary and secondary scrambling code, physical channels carrying data, and common broadcast channels, in case of cell splitting.

Fig. 2 also shows the base station 4 equipped with the e.g. smart antenna array 2. Further, the base station 4 includes a packet scheduler 5. The packet scheduler 5 can also be arranged remote from the base station 4 at an appropriate position.

For cells with beamforming SA, it is assumed that one PDSCH is being transmitted under each beam. This means that the PDSCHs transmitted under the same scrambling code, but different beams, all share the same root PDSCH channelization with a certain minimum spreading factor (SF) denoted  $SF_{PDSCH_{root}}$ . This is shown in Fig. 3.

Fig. 3 illustrates a channelization code tree for use under one scrambling code. The black nodes in the tree are reserved for PDSCHs under different beams. The root PDSCH code marked by a double-lined arrow is reserved so fast bit rate allocation/change can be accommodated for the different beams. Codes in the sub-tree below the root PDSCH code and circumscribed by a hatched circle can be used by PDSCHs in parallel beams. DCH's marked by simple arrows to the right of the hatched circle can use the rest of the tree.

Alternatively, one logical DSCH (Downlink Shared Channel) may be assigned per beam, so a separate root PDSCH channelization code can be reserved for each beam. However, this option will result in loss of code trunking efficiency, because it is highly unlikely that all PDSCHs under different beams will be operating at high bit rates simultaneously. Application of smart packet scheduling for parallel beams, performed by packet scheduler 5 of Fig. 2, can be designed to avoid such loss of code trunking efficiency. This will be discussed further below.

Using link adaptation (LA) techniques e.g. for one scrambling

code of Fig 3 or for a logical DSCH, the selected bit rate for each UE (user equipment) on the DSCH can be expressed as a function of the power allowed for the PDSCH and the experienced SIR (signal-to-interference-ratio) at the UE.

5 This basically implies that UEs close to the BS typically get assigned a higher bit rate, as these UEs have a higher SIR. However, a UE is not always assigned the bit rate according to the LA criteria based on reserved transmit power and SIR at the UE. There are other limitations such as the SF  
 10 (Spreading Factor) of the root channelization code which set an upper limit on the maximum bit rate.

In the following, aspects of the invention related to code reservation strategies will be described.

15

For cases where the PDSCHs under the same scrambling code, but different beams, share the same PDSCH root channelization code, a minimum assumed SF for beam number  $m$  ( $SF_{min}[m]$ ) will be introduced. This means that the SF of the root PDSCH code  
 20 should be selected according to the set of minimum SFs assumed for the different beams, i.e.

$$SF_{DSCHroot} = f(\{SF_{min}[m]\}_{m \in SC}), \quad (1)$$

where  $\{SF_{min}[m]\}_{m \in SC}$  is the set of assumed minimum SFs for the  
 25 beams transmitted under the same scrambling code, where the set SC contains the beam numbers which are transmitted under the same scrambling code. A conservative approach is to select the function  $f()$  so simultaneous transmission in all the beams under the same scrambling code is possible with the  
 30 minimum assumed SF. However, the probability of that happening is likely to be small, which lead to the conclusion that the latter approach would result in waste of code resources.



Assuming that one scrambling code will most probably cover C=3-5 beams, at least some of the embodiments of the present invention use the following simplified approach, where

$$\begin{aligned} SF_{DSCHroot} &= f(\{SF_{min}[m]\}_{m \in SC}) \\ &= Min\{\{SF_{min}[m]\}_{m \in SC}\} / Q \end{aligned} \quad (2)$$

5

with  $Q=2^n$  and  $C \geq Q$ , where n is a positive integer, i.e.  $n \in [0, 1, 2, 3, \dots]$ .

Assuming that the root PDSCH code is shared between e.g. C=4  
10 beams, then  $Q=4$  will result in a case where the reserved code resources allow for simultaneous transmission in all four beams with the minimum SF. Thus, code load becomes identical to the case where separate root PDSCH codes are reserved for each beam.

15

However, by setting  $Q=2$  (assuming C=4 four beams) one obtains a gain in terms of less reserved code resources. Actually, preferably 50% less code resources are reserved compared to the case where separate root PDSCH codes are reserved per  
20 beam. As an example, selecting  $Q=2$  (still assuming four beams), the embodiments of the invention can ensure that the beam with the minimum assumed SF can transmit at the maximum allowed bit rate, while the other PDSCHs under different beams (but same scrambling code) can be active at lower bit  
25 rates.

This choice also makes it possible that two PDSCHs are operated simultaneously at  $Min\{\{SF_{min}[m]\}_{m \in SC}\}$ , assuming that the remaining PDSCHs are silent.

30

Using smart packet scheduling for parallel beams, it can be avoided that all beams transmit on the PDSCH with high bit

rates (low SF) simultaneously. This is illustrated in the following.

5 In the following, aspects of the invention related to smart parallel packet scheduling will be described.

10 In order to illustrate the basic principles of smart parallel packet scheduling, an example will be considered where PDSCHs are transmitted under four beams, which all share the same root PDSCH channelization code. Under each of these beams, there are UEs (User Equipments) which can operate at high, medium, and low bit rates.

15 An example of an appropriate scheduling strategy, applied by packet scheduler 5 shown in Fig. 2, is illustrated in Figure 4. Here it is seen that the scheduling in the individual beams #1 to #4 is coordinated, so only one of the beams #1 to #4 is transmitting with a high bit rate during the same time period. The different time periods (say scheduling slots) are  
20 balanced so they require nearly the same amount of code resources.

A comparative example of poor scheduling is shown in Fig. 5. Here high bit rates are transmitted to two UEs  
25 simultaneously. This sets high requirements to the amount of reserved code resources, and should therefore be avoided whenever possible.

30 The proposed scheduling strategy can also be combined with quality-of-service (QoS) differentiation schemes, so packets are prioritized according to QoS attributes.

HSDPA is basically an extension of the DSCH. The presented invention is therefore also applicable for the HSDPA.

The invention provides a code efficient solution for cases where multiple beamforming PDSCCHs are applied. The method basically provides a code trunking efficient solution. This means that code resources are better utilized, so the BS can  
5 carry a higher amount of traffic (e.g. higher number of user) with less scrambling codes. This is a major advantage, as introduction of additional scrambling codes typically results in a capacity loss, as the orthogonality properties are partly destroyed within the cell. The present invention will  
10 therefore result in a capacity gain.

This gain is also present for HSDPA, even though HSDPA has the option of using higher order modulation schemes to avoid code blocking. This is true since usage of multiple codes  
15 (equivalent to lower SF) is more spectral efficient, compared to using higher order modulation techniques.

As mentioned earlier, the present invention can be implemented e.g. within the limits of the UMTS specifications  
20 (i.e. the 3GPP specifications). The best mode of the invention depends on the selected antenna array configuration, number of beams, scrambling code configuration, etc. For a typical scenario with a four element uniform linear antenna array and six beams, where two  
25 scrambling codes are used to cover three beams each ( $C=3$ ), it is proposed to select  $Q=2$ .

The proposed invention can e.g. be implemented in the RNC (radio network controller) and/or the BS, and can e.g. be  
30 part of a RAN (Radio Access Network), e.g. an UTRAN (Universal Terrestrial RAN) solution as well as IP-RAN.

The presented algorithm opens for effective utilization of the DSCH when using link adaptation techniques as well as  
35 HSDPA.

The invention furthermore improves throughput of packet mode data, e.g. in SA BTS (IP RAN).

5 While the invention has been described with reference to preferred embodiments, the description is illustrative of the invention and is not to be construed as limiting the invention. The invention may also be implemented in other ways, e.g. by combining, in any arbitrary fashion, one or  
10 more features of one or some embodiments with one or more features of other embodiments. Various modifications and applications may occur to those skilled in the art without departing from the scope of the invention as e.g. defined by the appended claims.

CLAIMS

1. A method for providing enhanced utilization of code  
 5 resource in a cellular systems, preferably a terrestrial  
 cellular CDMA systems, wherein a base station comprises an  
 antenna system which generates several beams, and a Spreading  
 Factor (SF) of the root channelization code sets an upper  
 limit on the maximum bit rate, wherein the Spreading Factor  
 10 of the root channelization code is selected according to the  
 set of minimum Spreading Factors assumed for the different  
 beams.

2. Method according to claim 1 wherein the root  
 15 channelization code is the root PDSCH code (PDSCH = Physical  
 Downlink Shared Channel).

3. Method according to claim 1 or 2, wherein in a case  
 where the channels under a same scrambling code, but  
 20 different beams, share the same root channelization code, a  
 minimum assumed Spreading Factor for beam number  $m$  ( $SF_{min}[m]$ )  
 is defined according to the following equation:

$$SF_{DSCHroot} = f(\{SF_{min}[m]\}_{m \in SC}),$$

25 where  $SF_{DSCHroot}$  is the minimum assumed Spreading Factor of the  
 root channelization code of a down link shared channel  
 (DSCH),  $\{SF_{min}[m]\}_{m \in SC}$  is the set of assumed minimum SFs for  
 the beams transmitted under the same scrambling code, where  
 the set SC contains the beam numbers which are transmitted  
 30 under the same scrambling code.

4. Method according to any one of the preceding claims,  
 wherein  $SF_{DSCHroot}$  is calculated according to the equation

$$\begin{aligned} SF_{DSCHroot} &= f(\{SF_{min}[m]_{m \in SC}\}) \\ &= Min\{\{SF_{min}[m]_{m \in SC}\} / Q \end{aligned}$$

with  $Q=2^n$ , where  $n$  is a positive integer, i.e.  $n \in [0, 1, 2, 3 \dots]$ .

5        5. Method according to claim 4, wherein  $Q$  equals or is preferably smaller than, e.g. half, the number of beams sharing the same root PDSCH code, the beam with the minimum assumed SF being allowed to transmit at the maximum allowed bit rate, while the other channels under different beams but  
10 same scrambling code can be active at lower bit rates.

6. Method according to claim 3, wherein the function  $f()$  is selected in such a manner that simultaneous transmission in all the beams under the same scrambling code is possible  
15 with the minimum assumed Spreading Factor.

7. Method according to any one of the preceding claims, wherein packet scheduling for parallel beams is provided in such a manner that not all beams transmit on downlink, e.g.  
20 PDSCH, with high or maximum bit rates (low Spreading Factor) simultaneously.

8. Method according to claim 7, wherein packet scheduling in the individual beams is coordinated so that  
25 only one of the beams is transmitting with a high bit rate during the same time period, and different time periods, i.e. scheduling slots, are balanced so they require nearly the same amount of code resources.

30        9. Method according to claim 7 or 8, wherein the packet scheduling is based on quality-of-service (QoS) so that packet are prioritized according to QoS attributes.

10. Method according to any one of the preceding claims, wherein the selection of the Spreading Factor, and/or packet scheduling is being applied to the downlink, preferably the PDSCH (PDSCH = Physical Downlink Shared Channel), or to High Speed Downlink Packet Access (HSDPA).

11. A system for providing enhanced utilization of code resource in a cellular systems, preferably a terrestrial cellular CDMA systems, comprising a base station having an antenna system adapted to generate several beams, wherein a Spreading Factor (SF) of the root channelization code sets an upper limit on the maximum bit rate, comprising a selecting means (1) for selecting the Spreading Factor of the root channelization code according to the set of minimum Spreading Factors assumed for the different beams.

12. System according to claim 11, wherein the root channelization code is the root PDSCH code (PDSCH = Physical Downlink Shared Channel).

13. System according to claim 11 or 12, wherein in a case where the channels under a same scrambling code, but different beams, share the same root channelization code, the selection means is adapted to select a minimum assumed Spreading Factor, a minimum assumed Spreading Factor for beam number  $m$  ( $SF_{min}[m]$ ) being defined according to the following equation:

$$SF_{DSCHroot} = f(\{SF_{min}[m]\}_{m \in SC}),$$

where  $SF_{DSCHroot}$  is the minimum assumed Spreading Factor of the root channelization code of a down link shared channel (DSCH),  $\{SF_{min}[m]\}_{m \in SC}$  is the set of assumed minimum SFs for

the beams transmitted under the same scrambling code, where the set SC contains the beam numbers which are transmitted under the same scrambling code.

- 5           14. System according to any one of the preceding system claims, comprising calculating means (1) for calculating  $SF_{DSCHroot}$  according to the equation

$$\begin{aligned} SF_{DSCHroot} &= f(\{SF_{min}[m]_{m \in SC}\}) \\ &= Min\{\{SF_{min}[m]_{m \in SC}\}/Q \end{aligned}$$

- 10   with  $Q=2^n$ , where n is a positive integer, i.e.  $n \in [0,1,2,3....]$ .

- 15           15. System according to claim 14, wherein Q equals or is preferably smaller than, e.g. half, the number of beams sharing the same root PDSCH code, the beam with the minimum assumed SF being allowed to transmit at the maximum allowed bit rate, while the other channels under different beams but same scrambling code can be active at lower bit rates.

- 20           16. System according to claim 13, wherein the function  $f()$  is selected in such a manner that simultaneous transmission in all the beams under the same scrambling code is possible with the minimum assumed Spreading Factor.

- 25           17. System according to any one of the preceding system claims, comprising a packet scheduler (5) for providing packet scheduling for parallel beams in such a manner that less than all beams, preferably only one beam, are allowed to transmit on the downlink, e.g. PDSCH, with high bit rates (low Spreading Factor) simultaneously.

30

18. System according to claim 17, wherein the packet scheduler (5) is adapted to coordinate packet scheduling in



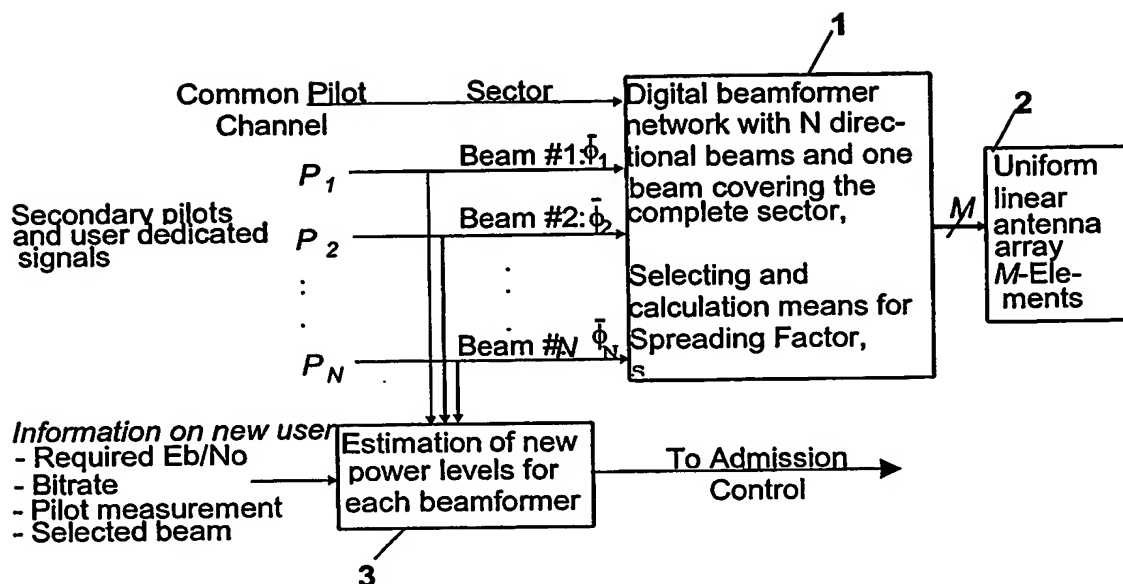
the individual beams so that only one of the beams is transmitting with a high bit rate during the same time period, and different time periods, i.e. scheduling slots, are balanced so they require nearly the same amount of code resources.

19. System according to claim 17 or 18, wherein the packet scheduler (5) is adapted to base packet scheduling on quality-of-service (QoS) so that packet are prioritized according to QoS attributes.

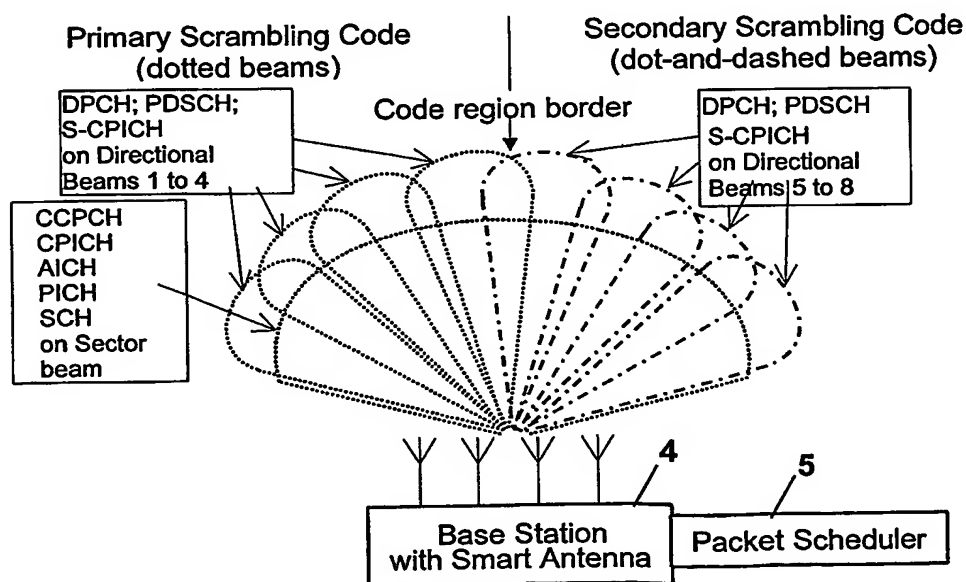
20. System according to any one of the preceding system claims, wherein the system is adapted to apply the selection of the Spreading Factor, and/or packet scheduling to the downlink, preferably the PDSCH (PDSCH = Physical Downlink Shared Channel), or to High Speed Downlink Packet Access (HSDPA).

21. Network element to be used in a method or system as defined in any one of the preceding claims, comprising a selecting means (1) for selecting a Spreading Factor of a root channelization code according to a set of minimum Spreading Factors assumed for different beams.

22. Network element as defined in claim 21, comprising a packet scheduler (5) for providing packet scheduling for parallel beams in such a manner that less than all beams, preferably only one beam, are allowed to transmit on the downlink, e.g. PDSCH, with high bit rates (low Spreading Factor) simultaneously.

**Fig. 1**

Block diagram of BS architecture when using smart antennas with a grid of fixed downlink beamforming.

**Fig.2**

Beam allocation of primary and secondary scrambling code, physical channels carrying data, and common broadcast channels, in case of cell splitting.

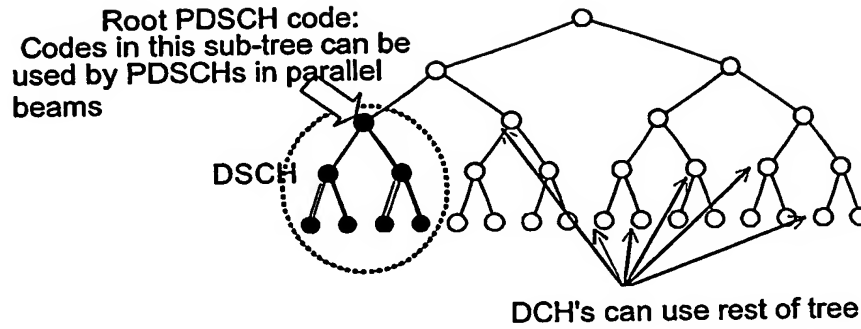
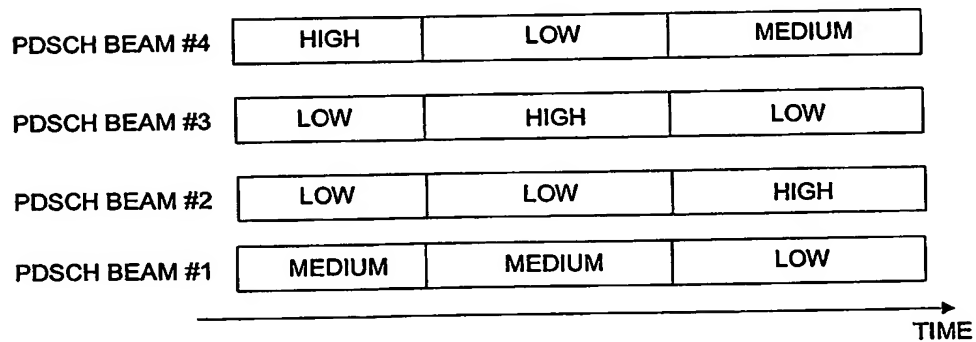
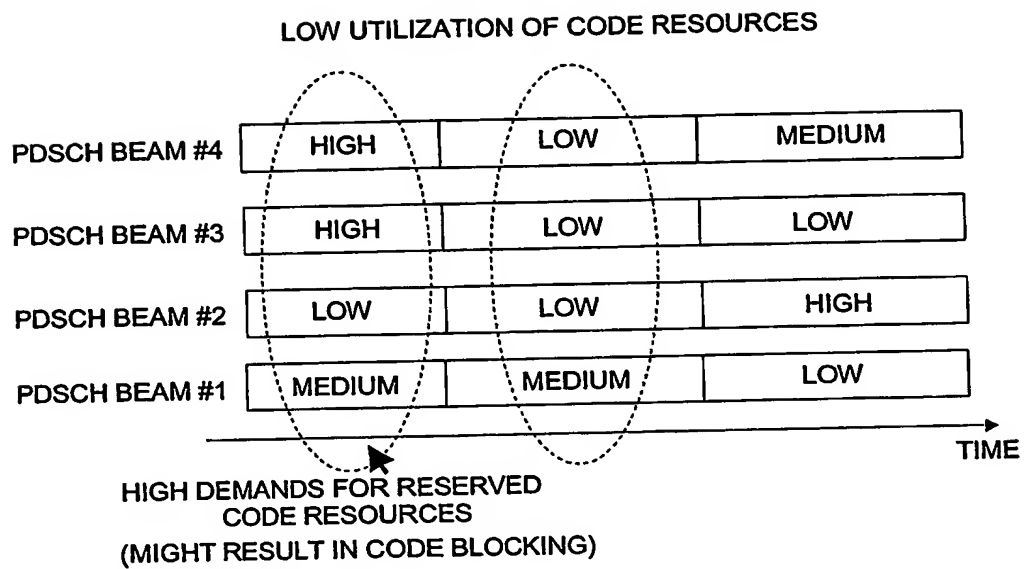
**Fig. 3**

Illustration of channelization code tree for use under one scrambling code

**Fig. 4**

EXAMPLE OF SMART PARALLEL PACKET SCHEDULING  
FOR OPTIMIZED CODE RESOURCE ALLOCATION



**Fig. 5**  
EXAMPLE OF POOR UN-COORDINATED PACKET SCHEDULING

## INTERNATIONAL SEARCH REPORT

In ..... onal Application No  
PCT/IB 02038A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 H04B1/707 H04B7/02

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04B H04L H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	R. AGUSTI (UPC) ET AL: "First report on the evaluation of RRM algorithms by simulation" IST-2000-25133:ARROWS D09, [Online] 15 May 2002 (2002-05-15), XP002229753 Retrieved from the Internet: <URL:http://www.arrows-ist.upc.es/publicationsdeliverables.htm> [retrieved on 2003-02-03] section 3.5.1-3.5.2 and 4.5.2 ---	1-22
A	EP 1 182 799 A (LUCENT TECHNOLOGIES INC) 27 February 2002 (2002-02-27) section 0008 - 0012 and 0048 ---	1-22
A	US 6 108 369 A (DAHLMAN ERIK ET AL) 22 August 2000 (2000-08-22) column 4, line 33 -column 5, line 44 ---	1-22
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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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## INTERNATIONAL SEARCH REPORT

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